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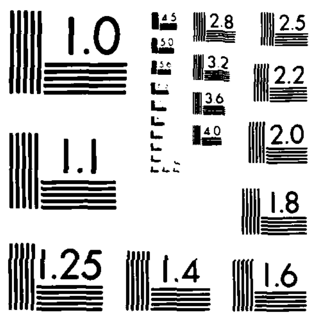

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BATTLE SIMULATION FOR COMMAND AND CONTROL TRAINING

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SUMMARY

In response to a strongly felt need for better capabilities for the training of battle staff personnel and the evaluation and analysis of command and control systems and capabilities, the Air Force is exploring the development of a Tactical Force Management Training and Analysis Facility (TFMTAF) to perform those functions. The intent of such a facility would be to use computer support to provide a realistic and challenging simulated combat environment that would respond to the actions of command and control personnel and systems in much the same way that a real combat environment might, allowing free play to a degree not currently possible in manual exercises.

But can such an environment be created by pitting the players against an automated model of combat, no matter how complex? This Paper suggests a need for a hybrid form of combat simulation in which the computer is used to complement and support the breadth and depth of understanding human controllers bring to their task.

Combat is a rich and complex phenomenon, and no model of combat can provide more than a limited and simplified abstraction of it. The purpose of the TFMTAF is to train combat decisionmaking skills, so it is particularly important that the representation of combat it projects to the players reflect those aspects of combat to which those skills are attuned. Computerized combat models are ill equipped to do this, because of the aspects of combat they emphasize and those they neglect.

Computerized models tend to emphasize the regularities of combat and play down the idiosyncrasies and variabilities to which good combat

decisionmaking must be sensitive. Computer models depict combat from a single perspective, usually as mechanical contest between opposing forces; competent human decisionmakers must maintain multiple perspectives on the same combat process and be able to switch back and forth between them in response to changing circumstances.

A hybrid simulator might overcome these limitations. It could be designed to take better advantage of the human-computer combination of capabilities than does any approach relying too much on either one alone. Such a simulation should be conceptualized as a conflict simulation run by a human control team supported by sophisticated automated aids and not as a computerized simulation operated and monitored by a human control team. Responsibility for understanding and directing the course of the conflict should remain with the control team, and the computer support should provide a form of automated "sand table," performing functions similar to those that sand tables have historically performed for military gamers. The advantages of such an approach for C^2 evaluation and analysis, the other functions of the TFMTAF, are also discussed.

CONTENTS

I. INTRODUCTION

In response to a strongly felt need for better capabilities for the training of battle staff personnel and the evaluation and analysis of command and control systems and capabilities, the Air Force is exploring the development of a Tactical Force Management Training and Analysis Facility (TFMTAF) to replace the existing Blue Flag exercise facility at Eglin Air Force Base, Florida. If built, the TFMTAF would support three conceptually distinct (though overlapping) areas of activity.

1. Training of command and control (C^2) personnel at all levels.
2. Evaluation of C^2 systems and processes.
3. Support for analysis of C^2 systems and processes.

Discussion of these areas and of the utility of such a facility to support them can be found in HQUSAF/SA (1980) and additional discussion of the utility of such a facility for evaluation purposes can be found in Callero et al. (1980).

Although the design of such a facility is still quite open, it would probably assume the general shape suggested in Callero et al. (1980). That is, it would use computer support to provide a realistic and challenging simulated combat environment that would respond to the actions of C^2 personnel and systems in much the same way that a real combat environment might, allowing free play to a degree not currently possible in manual exercises.

It is questionable whether such an environment can be created by pitting the players against a fully automated computer model of combat,

no matter how detailed and complex. Rather, what may be required is a sophisticated man/machine simulator in which the computer complements and supports the breadth and depth of understanding the human Controllers bring to their task. This Paper explores the reasons that this is so, with particular attention to the differences between mental and computerized representations of combat and the implications of those differences for simulator design.

This Paper emphasizes the training function of the TFMTAF. Section II outlines the concept of training underlying the ideas presented here. Performance depends heavily on the performer's internal perceptual models of the task environment--assisting the performer to acquire and maintain appropriate perceptual models is an important function of training. In addition to providing details about the task environment, these perceptual models give the performer a gestalt for the problems he faces--his overall perception of the task environment as a whole and his place in it. The representation of combat projected by such a training facility as the TFMTAF will be a major determinant in the quality of the training it provides.

Combat is a rich and complex phenomenon, and no representation can provide more than a limited and simplified abstraction of that phenomenon. The purpose of the TFMTAF is to train combat decisionmaking skills, so the representation it projects must reflect those aspects of combat to which those skills are most attuned. Section III examines some of those aspects and concludes that computerized combat models provide poor representations of them. It is doubtful, therefore, that conventional computerized combat modeling can provide an adequate basis for TFMTAF.

What may be needed is a hybrid form of man/machine simulation in which a human control team's world knowledge, judgment, and understanding are supported by the data storage and manipulation capabilities of modern digital computers. Section IV outlines some of the major characteristics a hybrid simulator might have and suggests directions in which its development might proceed. One of the major differences between developing a computerized combat model and developing a hybrid simulator of the type called for here is that the development of the control team needs to be given as much attention as does development of the supporting computer system.

The TFMTAF is not only a training facility but has functions concerned with evaluation and the support of analysis as well. The last section examines these functions in the light of the earlier analysis and argues that they would also be better served by a hybrid simulator than by one dependent on simulation based on conventional combat models.

Combat and computerized models of combat are different, with some of the major differences falling in areas central to human combat decisionmaking. If we fail to recognize this, and develop military capabilities fine tuned to fight computer models of combat, we may be putting our future security at risk. This possibility goes largely unnoticed in part because our usual conceptions of combat and combat models tend to emphasize the similarities and neglect the differences. Only by challenging those conceptions, and looking more closely at distinctions we usually overlook, can we bring the problem into focus well enough to decide how serious it really is. This Paper raises more

questions than it answers, but they are important questions; the fact that they may not have clear and straightforward answers should not be used as an excuse to ignore them.

II. A CONCEPT OF TRAINING

Any set of ideas about the kind of simulation needed to provide high quality C^2 training is necessarily based on some concept of what training is all about and what is required to do it. This section will sketch out the concept of training underlying the view of battle simulation presented here. My view closely parallels that presented in Dreyfus and Dreyfus (1979), and Dreyfus (1981).

Consider someone who has to perform in some task environment. He might be a Targets Analyst, Fighter Duty Officer, or Director of Combat Operations in a TACC; a chess or tennis player; or an automobile driver. In any case, the task environment makes demands on him and he must respond to those demands. At a general level, training is intended to help him learn how to perform and how to improve his performance. This leads to the question of what learning is all about.

People do not perceive the situation facing them directly. Rather, they perceive and act on the basis of internal models embodying their comprehension of the situation, combining new information obtained from the outside world with expectations and past experience in similar and related situations. The models reflect general knowledge about the world and how it works in the particular situation being dealt with.

Performance has two primary determinants. The first involves the internal models themselves and how functional they are for the task being performed. The second involves the way those models are used to perform the task and the actions taken on the basis of the models. Performance, then, depends on how the performer perceives his situation and what he does on the basis of that perception.

Learning has two corresponding components--(1) the development and refinement of the perceptual models on which comprehension and performance rest and (2) the acquisition and honing of the skills themselves. Effective training requires an environment in which both are facilitated in appropriate proportions.

These two components are intimately intertwined. The skills that can be acquired depend on the perceptual models available, because the performer can deal with the task only in terms of those models. He can notice and respond only to distinctions his perceptual models recognize. For example, a driver whose perceptual models distinguish few different gradations of road surface is more likely to skid in wet weather than one who can make finer distinctions, and an intelligence analyst with only a superficial understanding of Soviet doctrine and deployment patterns will see far less in his data than one with a finer-grained understanding.

The practice of skills that require differentiation can aid in the development of richer and more differentiated models. The driver can improve his ability to differentiate road surfaces by practicing controlled skidding, and the intelligence analyst can sharpen his understanding of Soviet doctrine and deployment patterns by studying and evaluating field exercises.

The acquisition of particular skills is the more obvious of these two components, and the one that usually receives attention. The underlying perceptual models are part of the unnoticed background, although nonetheless important. I will be giving more attention to the

perceptual models than to the specific skills, not because the latter are unimportant, but because the issues this Paper addresses relate more directly to the former.

One of the best ways of acquiring and refining the necessary perceptual models seems to be through a combination of attentive participation in the task environment and (possibly separate) directed study of particular relevant aspects of that environment. Thus, the tennis player who wants to improve reads and thinks about various aspects of the game and plays a lot of tennis. The chess player studies the games of the masters, does chess puzzles, and plays a lot of chess. The command and controller may study military history to understand the use of force in past wars, and think about how to practice his trade, but he cannot fight very many wars. Exercises must substitute. Past exercise technology has proved inadequate in many ways, and the TFMTAF represents an attempt to overcome those inadequacies (HQUSAF/SA, 1980).

The perceptual understanding acquired by direct experience with the (real or simulated) task environment serves the trainee in different ways. At one level it provides specific facts about the environment and specific procedures to use in particular circumstances. A fighter duty officer, for example, might learn what kinds of data can be found on various status boards and where to check on the availability of additional aircraft. These are the most obvious results of training, the things that can be tested by examination. At another level it provides the trainee with an overall gestalt for the task environment and the problems he faces--a coherent global pattern or context that gives meaning to the pieces and details. This gestalt is far less

tangible than the pieces and details and is difficult to pin down with precision but still plays an important role in performance. Even when the trainee's actions seem to be based on particular details, which details he responds to and how well he responds depend on his overall gestalt.

When knowledge and skills required by various jobs are identified and training goals to impart them are defined, the emphasis is usually on the specific facts and procedures needed to do the job. The gestalt is often neglected, even though it may be a significant product of the training process. The gestalt projected to the players by the TFMTAF will play a major role in determining the quality of the training provided, and the full training potential of the TFMTAF cannot be realized unless that fact is taken into account in its development.

Although its stated training objectives might be quite specific, the TFMTAF will probably be called upon to perform a wide variety of training with a broad and diverse population of trainees from throughout the Tactical Air Forces. Personnel will be trained in roles ranging from the Commander making high level command decisions at the top to the Targeteers, Fighter Duty Officers, and technicians implementing those decisions at the bottom. Full time professional C^2 cadre will use the facility to acquire and maintain their professional skills, both individually and as integrated teams. Introductory training will be provided to personnel who may be contingency augmentees to C^2. Personnel from the broader general TAF population will receive general orientation and familiarization with the C^2 system they will be called upon to work with in the event of an actual combat contingency.

Looked at separately, these different types of training appear to suggest quite different requirements. Top level training in command decisionmaking seems to require only highly aggregated representations of the conflict environment on which to base high level decisions about apportionment of air power between various missions or very generalized selection of campaign objectives. Training of personnel to function at lower levels, on the other hand, appears to require more highly detailed information about particular missions and targets, but not very much of the high level information. The requirements for free play and responsiveness to command and control actions appear to vary, as well, with less being required for general orientation than for the acquisition and maintenance of professional skills.

In fact, however, these levels and types of training may be less different than they superficially appear. Each might be enhanced by a realistic and responsive simulator in which all could be carried on together, allowing appropriate interplays among the various players and types of decisionmaking.

Viewed in isolation, command decisionmaking can be seen as a highly abstract and impersonal activity--making abstract decisions in some complex analog to chess. From this perspective, the job of Joint Task Force Commander is sometimes seen as involving little more than selecting apportionment percentages. But the commander's real job is to use his command and control system to employ his forces in a militarily effective way against a conscious and thinking enemy. He does not do this by making isolated, abstract, high-level decisions. Rather, he operates within and as part of the command and control system (indeed,

the larger conflict system) as a whole. Many of his important decisions are not decisions about force application at all, but decisions about people--whom to trust, whose advice to take, whom can be depended on to carry out his wishes, etc. He cannot be trained for these decisions by making abstract high level decisions in some complicated "board game" representation of conflict, but only by playing his role within a functioning command and control system.

Similar considerations apply at every level down the ladder. Each function can be characterized in terms of particular information in and particular decisions out. But useful as such characterizations may sometimes be, they are always incomplete. In particular, they neglect the participants' gestalt for their environment and their role in it and the effect that has on their performance. The closer the gestalt of the simulator comes to that of a combat environment, the more likely it is to engage the players' total participation in the same way that combat would, and the better the training likely to occur, whatever the training objective.

One particularly important aspect of that gestalt is the sense of purpose which the participants have about the enterprise on which they are engaged. Lack of purpose is a major weakness of many existing manual Command Post Exercises, and it may significantly contaminate the training such exercises provide. This lack of purpose stems from the high degree of pre-scripting and the lack of free play during the exercise. Little that the players do will materially affect the course of the exercise, and they know it. The commander has no unified battle plan or concept of operations, because none would be meaningful. His

decisions, and those of the people below him, become routine and proceduralized, with no central meaning or purpose (Gaines, Naslund, and Strauch, 1980).

Commanders get little useful training in such an environment, but it is sometimes argued that lower level participants can still be trained. It is true that people can learn certain mechanical skills and procedures, but they may internalize an image of a purposeless, mechanical activity in which filling out the right forms and checking off the right boxes are the most important activities, without any of the sense of teamwork and purpose necessary to a smoothly functioning and competent combat organization.

One of the potential benefits of the TFMTAF lies with its ability to overcome these kinds of limitations. If it provides a realistic and responsive combat environment, it can create the sense of purpose and unity of action a smoothly functioning combat organization should have, thus enhancing the training for all participants.

The extent to which this actually happens, of course, will depend on the nature of the combat simulation the TFMTAF provides. System designers and managers must think carefully about how human participants experience combat decisionmaking to ensure that the simulation the TFMTAF provides is attuned to that experience.

III. COMBAT AND ABSTRACTIONS OF COMBAT

Real armed combat between opposing military forces is an extremely rich, complex, and multifaceted process. No combat model or other characterization of combat can be more than a reduced and simplified abstraction that necessarily neglects, ignores, and misrepresents some facets of the process while it illuminates and emphasizes others. Brought to explicit attention, this seems so obvious as hardly to warrant mention. But it is easy to forget when we think in terms of a particular model or representation of combat that "combat is . . ." as characterized by that model.

The TFMTAF, in particular, will create a representation of combat each time it is run. It will project that representation to the trainees within the TFMTAF, as the exercise environment within which they acquire the experience of combat. From that environment those trainees will develop and refine their own internal models of combat, of the function of command and control in combat, and of their own roles within that system. It is important that the simulations reflect the elements of combat that figure significantly in human decisionmaking processes in combat and portray them in a realistic way.

In recent years the technology of computerized combat modeling has gained wide acceptance within the defense community, and this technology appears as an obvious source to draw on in developing the TFMTAF. But it may be less directly applicable than would appear, and its application without due attention to its limitations could seriously reduce the TFMTAF's potential effectiveness.

REGULARITIES AND VARIABILITIES

Combat is a highly variable process, with a lot of regularities. Each battle is unique, although trends and tendencies hold across battles. Any particular aspect of combat, such as the quality of the weaponry, the accuracy of the intelligence, or the morale of the troops may play differing roles in different situations. What is critical in one case may be of only marginal importance in another. Although an understanding of the principles and regularities of war is clearly important, human combat decisionmaking necessarily requires recognizing and exploiting the variabilities and idiosyncrasies of the particular combat situation--fighting and winning the war this time rather than some average war in which the regularities dominate.

In a particular situation, for example, the timing of an enemy offensive may be so critical that delay and disruption of the leading second echelon elements moving toward the front would ripple back and disrupt the entire offensive. The best use for tactical air in such a situation might be to pin those forces down to impose that delay, even if very little actual damage was inflicted in the process. A particular river crossing might be critical for a short period of time, because at the end of that time runoff from heavy rains upstream would swell the river and make it impassable. The ability to recognize and respond to such situations when they occur can play a crucial role in combat success, and it should be a major goal of the TFMTAF to create an environment in which such abilities are fostered and rewarded.

Computerized combat modeling generally concentrates on the regularities of combat and minimizes the effects of the variabilities.

Factors such as delay are seldom included at all, and if they are, they take on an average regularized character. For example, a model might have a fixed ratio between attrition and speed of advance, thus allowing delay to be introduced through the mechanism of attrition. But mechanisms of delay such as temporarily pinning down traffic at a river crossing while the river rises, with effects that propagate through and disrupt the whole enemy plan, are not included. They are too idiosyncratic and unpredictable, too hard to rationalize and validate.

Computerized combat models seldom treat leadership, morale, deception, and even "Murphy's law," which play significant roles in the course of real combat. Human perception, decisionmaking, and communication play only minimal roles in the conceptual abstractions on which those models are based. These choices may be reasonable ones for the usual purposes combat models serve--comparison of the performance of alternative weapons systems. To do that, after all, it is useful to hypothesize an environment in which the systems being compared are the major variables and the confounding effects of such factors as morale, stratagem, and the quality of the opposing leaders are minimized. But it is important not to confuse the model with the process--not to believe that real combat actually behaves the same as models do. A battle simulator for training human decisionmakers requires a very different representation of combat than does a combat model developed for study purposes, and it should be based on a very different kind of abstraction.

THE IMPORTANCE OF MULTIPLE PERSPECTIVES

Real combat is extremely complex, with a lot of things going on at once. Too much goes on, in fact, ever to get it all into focus with equal clarity. It is possible to see only a partial picture, to get only a limited perspective on this larger process. It is much like looking at or making a two-dimensional picture of a three-dimensional object. You can see only one view at a time, although the object itself is really much more than that.

Combat may be viewed from many different perspectives. It may be seen as a force-against-force contest, a slugging match whose outcome is determined by the relative combat power of the opposing forces. It may be viewed in terms of mass and maneuver, feint and counterfeint, so that aggregate combat power appears less critical than combat power delivered at the right time and the right place. It may be seen in terms that make the forces themselves secondary, giving greater prominence to other factors. It may be seen as a battle of information, for example, of stratagem, deception, and counterdeception. With the expiration of the British Official Secrets Act coverage of World War II, a number of memoirs stressing this view of that war have recently been published--e.g., Jones (1978).

Combat may also be seen as a personal contest between the individual leaders, in which the forces involved are simply the weapons those leaders wield. The North African campaign in World War II is frequently seen as such a contest between Rommel and Montgomery. This view is also prevalent in the writings of the 17th century samurai, Miyamato Musashi, renowned both as a general and an individual

swordsman. He saw the basic principles of combat as the same whether wielding a sword or wielding an army, and many of his writings make little distinction between the two (Musashi, 1974). Goldhamer (1979) provides a good review of different perspectives on the nature of combat and of how the dominant perspective has differed in different times and places.

In an actual combat situation, then, human decisionmakers may see the problems facing them in a number of different ways. A competent human decisionmaker may hold several different perspectives on an ongoing battle, switching back and forth between them quite rapidly during the course of his decisionmaking processes. The ability to do this, and to find and operate from the best perspective for a particular set of circumstances, are important combat decisionmaking skills, and the TFMTAF should foster them. To that end, it must provide a rich enough simulation of the combat environment to support multiple perceptions and perspectives and to respond appropriately to actions taken on the basis of those perspectives.

In evaluating a candidate set of air strikes, for example, a tactical air commander may want to assess the probable effects of those strikes in terms of the actual damage they are likely to cause, the disruption they might cause even at lower than expected damage levels, the attendant delay they might impose on planned enemy operations, and even the message the enemy commander may get from them about what is known of his plans and dispositions and about friendly capabilities to penetrate his defenses. Each of these would be legitimate considerations, with the question of the weighting highly dependent on

the circumstances. The combat environment projected by the TFMTAF should be rich enough to support assessment of proposed strikes along each of these dimensions and to respond realistically to the strike option chosen.

It is not possible to provide such an environment in a TFMTAF driven primarily by a computerized combat model. Any such model necessarily operates from a single perspective, usually one in which combat is represented as a mechanical clash of forces in which opposing forces move and affect each other in accordance with well-defined mathematical laws. In any particular model, most of the elements that may significantly influence the combat will be ignored or averaged out. And although it is less obvious, this is as true of the newer, heuristic modeling technologies as it is of the older, more formal ones.

The limitations of computerized combat modeling are most obvious in the representation and simulation of human decision processes. Modeling techniques now in use are unable to provide adequate representations of those processes. Newer techniques based on artificial intelligence appear to some to offer promise, but they have not yet proved themselves; and strong arguments have been made that they never will (Dreyfus, 1979). In spite of their apparent complexity, these techniques are applicable only to decisionmaking in well-defined micro-worlds--isolated context-free abstractions of reality. They do not and cannot adequately represent the way intelligent human beings deal with squishy and ill-defined problem situations of the kind arising in combat decisionmaking, using a broad base of experience and general world knowledge to understand and cope with the specific problem.

All this should not be taken as a blanket condemnation of computerized combat models, but rather as a frank assessment of their limitations. Like a picture taken from a particular perspective, a combat model shows only the aspects of combat that are visible from that particular perspective. It is always possible to add a little more detail, or to put in some additional piece, but the basic limitation remains. Just as a three-dimensional object is inherently too rich to be represented fully by a picture of that object, so is combat too rich to be represented fully by any computerized model.

Although human internal models of combat are also incomplete, they can be richer and more multidimensional, in the same way that human internal models of three-dimensional objects can have a depth and dimension pictures never possess.

If you think about a familiar object, such as your car, the image you see is probably two-dimensional, and far less sharp and detailed than a good picture of the car from the same perspective would be. But if you then think about some feature of your car not visible from that perspective--the tail lights, for example, if you are visualizing a front view--your perspective shifts, and the image in your mind changes to one including that feature. You can make this kind of shift instantly because your internal model of the car is three-dimensional; you could never do that with a two-dimensional picture.

Something analogous to this is true of the internal model of a phenomenon like combat held by a knowledgeable expert (Strauch, 1980 and 1981). When the expert tries to answer any given question, he will generally do so from a particular perspective--seeing the battle as a

mechanistic interaction between opposing forces, for example, or as a contest of wits between opposing commanders. But the expert knows more than he can bring to consciousness at any one time, just as you know more of your car. He can choose an appropriate perspective for the question being asked, and he can shift perspective rapidly if the situation demands it. These things cannot be done with a computerized model, representing as it does a single perspective.

Pictures can be useful representations of objects, and computerized combat models can sometimes be useful representations of combat. How useful depends on the situation and the need. In the case of the TFMTAF, existing and foreseeable computerized combat modeling technology does not provide an adequate base on which to build a battle simulator with the richness and authenticity necessary to provide high quality training.

I am not arguing, of course, that everyone who knows something about combat necessarily knows more and can predict combat outcomes better than any computerized combat model. That is certainly not the case. However, the human mind has a <u>potential</u> for in-depth understanding of such phenomena as combat that cannot be equaled or even approached by any computerized model, no matter how quantitatively complex. Not everyone uses anything like his full potential, of course; most people use only a limited portion most of the time, but we should not therefore conclude that there is no potential and ignore it. Rather, we should recognize the potential and encourage its fuller utilization.

IV. HUMAN AND COMPUTERIZED MODELS OF COMBAT

The unique human potential for multidimensional in-depth understanding of combat is important for the design and operation of the TFMTAF as it relates to two distinct groups of people--the players and the control team. If the TFMTAF is successful, players who use it will come away from the experience with their understanding of combat significantly enhanced. The control team will serve as a major source for that enhanced understanding, and the TFMTAF might even be thought of as a mechanism for transferring understanding and knowledge from the control team to the players. It would be a mistake to believe that the players could learn from a computerized combat model in the absence of a competent and dedicated control team.

As noted earlier (Sec. II), the artificial combat experience gained from the TFMTAF will assist the players in acquiring and refining their own internal models of combat and of the roles they play in combat. The internal mental models people develop tend to reflect their environment. The gestalt projected by the TFMTAF, therefore, will have a significant effect on the perception of combat the players develop.

In particular, if the simulated combat environment provided by the TFMTAF is fairly flat and two-dimensional (as it is almost certain to be if the simulation is produced by a computerized combat model), the players may develop fairly flat and two-dimensional internal models. If that environment is one in which things generally go according to planning factors and such idiosyncratic situations as a rapidly rising river never seem to make a difference, they may internalize models of

combat in which only the regularities matter and there is no need to look for and respond to the peculiarities and idiosyncrasies of the particular situation.

But war and computer models of war are different. If we develop combat commanders and battle staffs who derive their understanding of war too heavily from computerized models, we both do them a disservice and put our future security at risk. If they have to fight a future war it will be the real thing and not a computer simulation, and a command and control apparatus insensitive to the difference is not likely to do very well.

The limitations faced by human beings acting alone to simulate a large scale combat environment are real and widely recognized (Callero et al., 1980). There is too much detail to be kept track of, too many things to be plotted, calculated, and updated, for the job to be done effectively by a manual control team. Indeed, it was largely to overcome these limitations that the TFMTAF was conceived in the first place. The limitations of computer models are less widely recognized, although they are just as real and as potentially damaging to the quality of training.

But while humans alone and computers alone both have limitations, their capabilities are complementary, and each can serve to overcome the limitations of the other. To realize this potential, the world knowledge, understanding, and judgment of a competent human control team must be supported (and not supplanted) by the data storage and manipulation capabilities current computer technology can provide. It is not always appropriate to automate everything that can be automated.

Functions within the TFMTAF should be automated only on the basis of a carefully considered judgment that its performance would be thus enhanced.

I am suggesting a different way of thinking about man/machine combat simulation, in which the representation driving the simulation is seen not as a computerized model that lives in the memory of the computer alone but as a hybrid that resides partly within the computer and partly within the individual and collective consciousness of the control team. I now want to look briefly at what a simulator developed from such a perspective might look like and at some of the considerations that might arise in that development.

WHAT A HYBRID SIMULATOR MIGHT BE LIKE

The most important characteristic of the sort of hybrid simulator being proposed here is the idea, rather than the particulars of the implementation. The hybrid simulator should be conceptualized as a conflict simulation <u>run by a human control team</u> and <u>supported by</u> sophisticated automated aids, not as a computerized simulation in which the human controllers play secondary monitoring and directing roles. The responsibility for understanding and directing the course of the simulation should rest with the control team, and the computer aids available should be thought of as a kind of automated "sand table," performing the same kinds of functions sand tables have performed for gamers throughout military history. Only in this way can the multidimensional human understanding of conflict discussed earlier really be brought to bear in the simulation process.

A large scale combat simulation clearly has too much going on to expect a human control team to give detailed attention to all, or even a large percentage of the decisions required in the running of the simulation. Therefore, the computer should handle much of the routine detail in such a simulation. But the human controllers should monitor the flow of those decisions on a continuing basis and should be able to step in at any time and override the computer's handling of any portion of the war. This kind of intervention should not be a rare occurrence, but should happen on a regular basis in those areas where the computer representation does not adequately handle the aspects of the war players are considering in their decisionmaking process.

In conventional computerized combat modeling, the war is generally represented to the same level of resolution or "grain" all across the front. This level is determined by the size of the opposing forces and the computational capacity available. If the model is to be used to investigate command and control decisions, the level of detail would generally be chosen to be at least as fine as the average level required to support those decisions. Brigade level representation might be considered fine enough to model decisions made at corps level or above, with battalion level representation necessary to support modeling of division level decisions. A single representation is chosen for each type of combat interaction considered. As noted earlier, this representation is generally based on a single perspective view of combat as the mechanical interaction of forces.

This approach is satisfactory for a combat model intended to grind out weapons system evaluations, but it is not adequate to train human

beings in command and control decisionmaking. When we think about human understanding of combat, the idea of an "average" level of detail of interest at any particular command level must be tempered by the knowledge that large deviations from that average are certain to occur. Players may follow the ground action at no more than brigade or even division level over most of the front, but they may be interested in what is going on at a very fine level of detail in a few specific locations or circumstances. Neither will any single representation of combat interactions be adequate for all cases. In a theater level conflict, most of the force application decisions made by the players will probably be fairly average decisions, made on a more or less routine basis using standard planning factors and force application procedures. Some decisions, however, will be (or at least should be) based on much more careful consideration of the particulars of the situation.

There are, for example, fairly standard and straightforward ways of representing the effects of air strikes on the movement of second echelon forces. But these representations are not "laws of nature" describing what really happens in combat; they are only statistical approximations that *represent averages and misrepresent individual cases*. They will suffice across most of the front, most of the time, because the players will be assigning forces on the basis of the averages and will not be concerned with the particulars of any specific situation. If a situation arises in which they are concerned with the particulars, however, the standard representations may be totally inadequate. The critical river crossing hypothesized earlier might be

an example. In such a situation, the control team should take over and determine the outcome based on a representation appropriate to the situation and the players' perceptions of it.

Computer support for a hybrid simulator cannot be limited to a single level of resolution or a single representation of any particular combat interaction. Capabilities should exist to determine the effects of the same combat interactions in a number of different ways, corresponding to different perspectives on those interactions. Some of these determinations might involve fully automated outcome calculations, and others might involve supplementary calculations to support manual outcome determinations. The data base mechanism must allow all types of outcome determinations to be easily integrated into the data base to update the situation. The data base should also have the ability to represent different portions of the combat situation with different "grains" and to shift the representation from one grain to another as required.

It is difficult to imagine how these things might be done in the sort of single, integrated structure we usually think of a combat model as having, because of the difficulty of tying together all the logic necessary to keep the various calculations and levels of representation straight and consistent. In a hybrid simulator, much of this integrating logic can be handled by the control team on an ad hoc basis. Just as the control team in a manual exercise can use a small scale map to plot most of the action, with larger scale maps used to keep track of more detail in areas "where the action is," so should the control team in this hybrid simulator be able to use automated data bases at various levels of detail.

This implies a need for a highly competent control team with a thorough understanding of the computerized aids at their disposal, as well as of the combat processes they are responsible for simulating. Some might argue, in fact, a higher level of competence in the control team is needed than is attainable in practice. A counterargument can be made that no facility can provide good training without competent trainers, and to attempt to do so would be a serious mistake.

The hybrid simulator should attempt to maximize the synergy between the human controllers and their supporting computer. In general, people have better capabilities for a broad understanding of multidimensional phenomena and for identifying the particular aspects of the phenomenon likely to matter in a particular situation, and computers have better capabilities to store and manipulate large quantities of detail and make complex calculations. Even this generalization must be qualified, however. A computer can handle large amounts of detail to some prespecified level of detail, while a human can shift focus and jump from one level of detail to another as appropriate to the situation. No human could keep track of the amount of detail across a theater of conflict that a computer could manage, but neither could any computer maintain, across the full theater of conflict, all the detail a competent human decisionmaker might want to consider in particular situations.

The basic understanding of combat that drives the simulator should reside with the people on the control team. The functions of the control team should include keeping track of the state of the conflict,

providing necessary information to the players and receiving communications from them, making decisions for actors not represented by the players, and determining the outcomes of combat interactions and updating the situation accordingly. Responsibility for decisions about combat interactions and their effects should remain with the control team, even though the computer will provide significant automated support for those decisions.

The computer support should provide a basic representation of the conflict environment (data base), and capabilities to access and manipulate that data base. It should also provide bookkeeping and message handling capabilities of various kinds, as well as some models for the estimation of various kinds of combat outcomes or other relevant aspects of the conflict process. These might or might not include "combat models" in the usual sense of that term. The computer system should be designed and structured to support the control team but not necessarily to function as an integrated combat model.

DEVELOPING A HYBRID SIMULATOR

A hybrid simulator of the sort proposed here will necessarily require a different form of development than that associated with conventional combat models. A detailed development plan is beyond the scope of this Paper. All that will be attempted here, therefore, is identification of some of the most significant differences and a bare outline of a developmental sequence.

One major difference lies in the fact that simulator development usually concentrates on the computer model alone. The people involved

get little conceptual attention. What they do get generally emphasizes how they will operate and interact with the computer model, thought of as something separate and distinct from them. This is in keeping with the conceptualization that the computer model is the representation of combat being developed, and the people are not an integral part of that representation.

In the case of the hybrid simulator, however, the situation is quite different. The control team forms an integral human component of the representation being developed. The overall development process, then, must give considerable attention to "development" of that human component, to achieve fidelity of combat simulation.

The control team must have a deep understanding of both the processes of combat and of the computer assistance and support the TFMTAF provides them. People with all the requisite skills and capabilities probably do not exist at the present time, but such people must be developed as part of the development of the TFMTAF. Probably the best way is to start with a competent cadre of experienced personnel and allow that cadre to develop itself and the TFMTAF at the same time. This core cadre should include experienced exercise controllers (probably from the existing Blue Flag control team), experienced computer personnel, and personnel selected for their operational expertise with various aspects of combat.

The basic understanding of combat that drives any simulation plays a major role in determining the nature of that simulation. In the case of most computerized combat models, this understanding comes from the model designers and is frozen into place when the model is written.

Moreover, as we saw earlier, the model can reflect only a fraction of its designers' understanding, because it necessarily depicts combat from a specific, limited perspective.

A hybrid combat simulation, however, will derive its understanding of combat from the control team itself. It should be possible to utilize a much higher fraction of that understanding than is the case with a computerized model, because the control team can operate from multiple perspectives and can shift from one to another during the simulation. The conceptual understanding on which the hybrid simulation rests will not be frozen at the time of model design as with a computerized model but should grow and improve as the control team itself develops.

The control team's initial level of sophistication about the simulation of combat will probably be about the same as what currently exists at Blue Flag. As they gain experience with the TFMTAF, however, their level of sophistication and understanding should increase rapidly. This increasing sophistication should then reflect directly back onto the simulation provided, thence to the quality of training players receive from the TFMTAF.

The computerized component of the hybrid simulator will have much in common with existing large computerized combat models and will require some of the same kinds of expertise in its development. At the same time, there are significant differences between the two that must be taken into account if the hybrid development is to be successful. The computerized component of the hybrid simulator must be evolved as a set of computerized aids to a sophisticated human-directed simulation, not developed as a free-standing combat model.

The conventional developmental approach of defining a set of requirements and specifications and then hiring a contractor to build a system that meets those specifications is not likely to do the job. No clearly defined base of experience exists from which to write the required specifications or to build a system from specifications if they could be written. Instead there must be a long term cooperative relationship between the contractor and appropriate Air Force personnel, including the control team, to define and evolve the required capabilities.

The initial computerized aids should probably include data base and message handling capability and perhaps an existing intelligence message generation capability such as that provided by the TACSIM simulator. Specific capabilities should be worked out between the contractor and the Air Force cadre who will run the TFMTAF and should be matched to initial control team operations. Considerable excess computer capability is needed to allow the computerized support to be readily expanded as operational experience is gained with its use. This must be recognized as a developmental activity breaking new ground, not something well enough understood to be mapped out in detail in advance.

The most important element of the process is probably a competent cadre of both Air Force and contractor personnel dedicated to the development of a hybrid simulator as a new form of combat simulation and committed to the development process for a long enough time to gain and exploit the required experience. They should begin from existing manual war gaming and simulation technology, not computer modeling, and ask

what limitations in manual simulation can be pushed back with appropriately designed automated aids, and how. Development should then be an evolutionary process of deciding what new aids are needed, developing those aids, gaining experience with their use, and reassessing needs.

The goal of a computer-assisted, human-directed multidimensional simulation of combat as it appears to a human participant must be kept in mind at all times. This means, in particular, that judgments about what needs to be simulated (and how) should be made by military professionals with rich, multisource internal models of combat on which to base them, not by those whose understanding of combat is primarily an intellectual one derived from the modeling process.

V. THE TFMTAF AS A TOOL FOR EVALUATION AND ANALYSIS

Thus far, I have concentrated on the TFMTAF as a training facility. It also has two additional functions, evaluation of and support for the analysis of command and control.

The analysis of combat has come to play a major part in defense planning, and combat models have achieved considerable face validity within the defense community. Command and control, however, has proven to be one of the most elusive and difficult aspects of warfare to model, and efforts to date have not achieved notable success, partly because modeling is most successful for straightforward and well-defined physical processes, and far less successful where behavioral issues are involved. Command and control is a complex human process, where behavioral issues have a prominent and decisive role. Most combat modeling treats combat as a fairly mechanical process in which opposing forces butt heads according to a few straightforward control rules, with none of the complexity or sophistication exhibited in actual combat. Some hope that new modeling approaches such as those provided by artificial intelligence will provide the means by which this situation can be changed, but that remains a hope and not a reality.

The TFMTAF would support the analytical community in two different ways. First, it would provide a testbed for the development and evaluation of modeling tools and techniques for use within the analytical community. Second, it would provide a combat "laboratory" within which artificial experience gained in exercises could be collected for use as a data base against which to compare and validate

analytical results. In this, it would play a role similar to that played by historical combat experience.

Among the advantages the TFMTAF would have in comparison with historical experience, it can provide far more controllable and repeatable experience than actual combat, involving current and future weapons and conditions rather than those from the past. That experience can be instrumented and documented in ways that are not possible in combat, and selected portions can even be rerun. The main disadvantage is that the experience gained will be artificial and may prove to be incorrect. The best defense against this possibility is to strive for a realistic and robust representation of combat not excessively driven by any particular set of narrowly conceived criteria.

The fundamental thesis underlying this Paper asserts that the Air Force and the U.S. defense community at large currently place too great an emphasis on external models (computerized and otherwise) as the source of our understanding of combat and the use of military forces in combat. This leads to an overreliance on the intellect, and a neglect of other, equally valid mechanisms such as intuition, gestalt understanding, and the ability to maintain and shift between diverse perspectives on a complex problem. This is not to argue that we should discard intellect in favor of these other mechanisms, but that we could benefit from a better balance in which each was accorded its appropriate role.

This thesis has significant implications for our capabilities to cope with military conflict. It suggests that our basic understanding of the phenomenon of conflict is not as good as a more even and balanced

use of all our cognitive abilities might provide and that our capability to apply military force in conflict may suffer as a result.

If developed in the manner suggested here, the TFMTAF provides a vehicle through which this thesis may be explored and tested. The simulation of combat based on a synthesis of internal and external models of combat allows assessment of the capabilities and limits of external models alone in ways that are not possible in a comparison of one external model with another--the usual form of model validation. The TFMTAF provides support for the analysis of command and control unattainable by any other means.

Similar considerations apply with respect to evaluation. Any evaluation of military systems in peacetime is necessarily artificial in that it takes place relative to some representation of the combat environment within which those systems will be used, and not in the actual environment. The adequacy of evaluation thus depends on how well the representation used reflects aspects of the real environment that are important to the performance of the system being evaluated. External computer models often poorly reflect some of the aspects of conflict most critical to command and control system performance, such as the idiosyncrasies of the particular situation and the multidimensional nature of armed conflict. A TFMTAF of the sort suggested here should provide a capability to subject command and control systems, procedures, and personnel to a far more realistic combat environment than is otherwise possible, thus providing an excellent facility for command and control evaluation.

Evaluation is often discussed as if it were a highly structured and well-understood process of making formal comparisons of well-defined attributes of the alternatives being evaluated in order to obtain objective characterizations of their relative merits. There is some of that, to be sure, but command and control evaluation also involves exploring and trying to understand ill-defined processes for which we have only very poor characterizations in the formal terms that we sometimes think of as equivalent to understanding. Evaluation involves forming opinions about the merits and demerits of the alternatives being considered and trying to support those opinions and communicate them convincingly to higher level managers and decisionmakers who need that knowledge. It involves a lot of piecemeal gathering and manipulating of data to produce "results," but it also requires holistic understanding of the processes being evaluated to guide the manipulation and to provide a basis for reasonable interpretation of the results obtained.

The TFMTAF will be used to support all these styles and varieties of evaluation, and probably more as users develop new means for exploiting the new capabilities the simulator will provide. This range of evaluation requirements can be better met by a simulator designed to provide a rich and responsive representation of combat than by one designed to meet narrowly defined design criteria derived from particular evaluation objectives or measures of merit. A hybrid design of the sort suggested here appears to be the best, if not the only, way to provide such a representation.

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